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Technical Research Note 193

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SIMPO-I ENTITY MODEL FOR DETERMINING THE QUALITATIVE IMPACT OF PERSONNEL POLICIES

Elizabeth Niehl and Richard C. Sorenson

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BEHAVIORAL SCIENCE RESEARCH LABORATORY

An activity of the Chief, Research and Development

J. E. UHLANER
Director

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Colonel, GS
Commanding

NOTICES

FOREWORD

The BESRL Task, "Computerized Models for the Simulation of Policies and Operations of the Personnel Subsystem--SIMPO-I", is conducted by the Statistical Research and Analysis Division. The Task constitutes the initial undertaking of an operations research requirement described in the Army Master Study Program under the title, "A Simulation Model of Personnel Operations (SIMPO)" and is Project 2J050222M711, "Army Operations Analysis", under the auspices of the Army Study Advisory Committee. Subtasks include: a) Operational Analysis of Personnel Subsystem; b) Cataloguing and Integration of Existing Manpower Models; c) Development of Measures of System Effectiveness; d) Development of Modeling Techniques; e) Design and Programming of SIMPO-I; f) Application and Evaluation of Computerized Models; and g) Problem Oriented Language for Management.

The effort is closely allied to the SRAD Task, "Optimization Models for Manpower Operations Research", under Army Project 2J024701A732, FY 1968 Work Program. The advantage of pursuing the optimization and simulation research in juxtaposition is that system simulation provides the most efficient and economical means of determining amount of gain and costs of implementing given policy alternatives.

The present publication reports on the development of the entity simulation model designed for inclusion in the SIMPO-I library of computer programs.

J. E. UHLANER, Director
U. S. Army Behavioral Science
Research Laboratory

Technical Research Note 193

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BESRL Technical Research Reports and Technical Research Notes are intended for sponsors of R&D tasks and other research and military agencies. Any findings ready for implementation at the time of publication are presented in the latter part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

SIMPO-I ENTITY MODEL FOR DETERMINING THE QUALITATIVE IMPACT OF PERSONNEL POLICIES

BRIEF

Requirement:

To simulate military personnel subsystems in order to predict and assess the total result of policy changes and to develop computer-aided research methods and tools that increase the Army's in-house capability for responding to personnel management research requirements.

Research Product:

The generalized entity simulation model which has been installed and tested on the computer system in BESRL's Statistical Research and Analysis Division serves to model characteristics common to a general class of personnel functions. An entity simulation is one in which individuals are explicitly represented as opposed to a mass flow model in which only characteristics of groups of individuals are specified. The basic population from which simulated individuals are randomly sampled is the multivariate normal, although the non-random sampling which often results in non-normal distributions may also be simulated. Option of optimizing performance of a sample over multiple job categories is built into the model, and criterion measures can be related to results of optimal allocation. Processing of manpower information may be simulated by use of linear transformations. The computer program is written so that modifications can easily be made to incorporate special features in the model.

Utilization of the Research Product:

The intention is to incorporate the initial generalized model in the SIMPO-I computer program library. It is intended that this model, after further modification, will become a module in the SIMPO-I simulation package for evaluation of personnel and manpower policy alternatives across the Army's major personnel functions. The entity model concentrates on the procurement, selection, and allocation aspects of the personnel system.

SIMPO-I ENTITY MODEL FOR DETERMINING THE QUALITATIVE IMPACT OF PERSONNEL POLICIES

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SIMPO-I ENTITY MODEL FOR DETERMINING THE QUALITATIVE IMPACT OF PERSONNEL POLICIES

BACKGROUND AND FUNCTION

A generalized entity simulation model has been successfully installed and tested on the computer system of the U. S. Army Behavioral Science Research Laboratory. This model is described in the context of the management research requirements for which it was designed and of the research design considerations which influenced its development. It is designed for inclusion in the computer program library of SIMPO-I.

SIMPO-I, when completed, will consist of a relatively comprehensive computerized model of the Army personnel subsystem--in effect, a simulation package and a library of computer programs. The simulation package will be capable of reflecting the trade-offs across major personnel functions that would result from the implementation of specific sets of personnel and manpower policies. The SIMPO-I library will contain computer programs implementing highly specialized simulation models as well as programs intended as computational devices for obtaining parameter values for entering into the simulation models.

The simulation model reported here was designed to function as a stand-alone program for inclusion in the SIMPO-I library. However, the entity model will also be modified to constitute the procurement, selection, and allocation module of a more comprehensive model developed under the SIMPO-I research effort. Other modules will depict such personnel functions as distribution, tour rotation, promotion, and training and will have appropriate interfaces with the entity model reported here. The entity model is not intended to be the primary means of simulating these latter functions, although the model can portray these functions efficiently for a variety of policies.

Personnel System Problems

Answers to many questions that arise in the course of military manpower planning await the development of more effective investigative methods. Too often objective investigation of important questions has not been feasible with the tools available to personnel and manpower management officers. Experimental studies involving the real manpower system are expensive both in cost of data collection and in reduced efficiency of the manpower system, in particular when the policy being tested operationally is found to be grossly inadequate. Evaluation of alternative procedures can be relatively inexpensive, however, if the personnel system can be modeled and the experimental results can be based on a computerized simulation of the system. Relationships between requirements, assignment procedures, input from outside the system (for

example, from external procurement or from training facilities), quantity and quality of personnel information made available to the system, attrition of the system, and measures of system effectiveness have been successfully studied through computer simulations.

Problems related to assignment of personnel to jobs or job categories form a major subgroup of problems which can be profitably studied through simulation models. The interests of manpower management offices often center on the comparison of alternative policies for assigning enlisted men to meet prescribed minimum qualification standards. Policy may specify as objectives the sequential minimization of transportation costs, an increase in the number assigned to their preferred occupational area, and optimization of expected performance on the job (as predicted from scores on paper-and-pencil tests or from other information recorded in the personnel folder). Different policies may change the order in which pertinent variables are optimized or may create a need for varying degrees of partial optimization at each stage. Related problem areas which may be examined by means of a simulation model may involve 1) designing testing programs for personnel assignment, 2) formulating policies which change standards for enlistment and induction, and 3) estimating the impact of increased mobilization on the quality of assigned men. Analytic approaches which would handle problems of this level of complexity have been proposed (1) but have not proved economical. Results which could serve as actual solutions to these problems have been heavily based on simulation techniques.

The simulation approach is particularly necessary when some use is made of optimization techniques within the system to be evaluated. Expected output for a modeled system is often examined, for example, after simulated individuals in a sample have each been assigned to a job in such a way as to maximize the average expected performance for the sample. The assignments may be based in part on linear programming algorithms. The beneficial application of such optimization methods has been demonstrated even when the metrics which characterize a personnel system are not of the interval type assumed in the derivation of the techniques involved (2).

Certain problems require special attention in designing and using system models for simulation experiments, notably the choice of suitable research design and of appropriate criterion variables. Also of interest is the more general issue--the type of model to be developed. First, the experimenter must ascertain whether a deterministic model is adequate for his purpose. With a deterministic model, one evaluation yields the results of interest, since the output is exactly determined by input, with no random variations to affect results. In some systems, however, there are variables that cannot be fully controlled by either laboratory or statistical techniques. The effect of variation in these variables resembles that of random fluctuations. Also, the magnitude and the distribution characteristics of the variations may relate to a relatively complex function of variables that fluctuate randomly. Hence, stochastic

models are used in which the randomness of the system is represented by random variables with specified probability distributions. The latter approach is thought to be generally more appropriate for simulations involving the personnel system.

The random variation characteristic of the real system can be easily simulated if the population of interest can be represented by a known statistical distribution. Samples are constructed by generating random numbers and then transforming these numbers to yield observations which can be expected to have the statistical properties of the population scores. This "model sampling" is performed repeatedly to insure against basing conclusions on a non-typical although random sample of simulated entities. Similarly, replications permit an evaluation of the criticality of the chance input into the system and provide a forecast of output fluctuations which can be expected under operational conditions.

The stochastic approach often becomes necessary when a practical solution to some particularly complex problem must be found, for example, to ascertain the consequences of applying a set of rules to select, assign, train, and distribute individuals. Suppose, however, the distribution of personnel according to policies involving minimum qualifications, quotas, and optimal assignment rules can be described as a fairly complicated set of mathematical functions. This, indeed, may be possible. To make the model workable, however, multiple integrals, possibly with variable limits, would have to be evaluated. Many such integrals--involving most multivariate distributions of interest--are impossible to evaluate analytically, and a numerical analyst would probably resort to a "Monte-Carlo" solution, making use of "clever" variance reduction techniques. Such an approach, however, would be a very specialized type of model sampling.

Furthermore, when the flow or any other manipulation of individuals according to prescribed policies must be simulated, either real records must be sampled or artificial persons must be generated. Real records cannot be sampled when hypothetical policies that have never been implemented are under study. Nor is it possible to simulate meaningfully a sample which exactly characterizes the population of interest. Instead, the solution is to generate observations which have the same statistical properties in all essential respects as if they had been drawn as random samples from the prescribed population. Again, this process is a stochastic one.

RESEARCH DESIGN CONCEPTS

Many of the applications appropriate for the SIMPO-I simulation model described in the present Research Note would use an optimal assignment model as a means of describing the idealized assignment system. Some studies deal with policies for assigning personnel so as to maximize average predicted school or on-the-job performance. In

other studies, a set of policies that utilize optimal assignment procedures at some point in the system may be included only as a standard against which to compare other policies. In any case, a simulation of the input and distribution of enlisted men through individual careers should utilize the wealth of data that relates performance in many different jobs to a wide range of predictor variables. Numerous studies have established the adequacy of linear equations in predicting such performance.

When it is desired to maximize accuracy of estimates of performance in a job, coefficients of the optimum linear function of a set of predictor variables are obtained according to least-squares regression techniques. The question might be raised whether these least-squares predictions will also be the appropriate parameter values when it is desired to allocate men to jobs in such a way as to maximize the average predicted performance of all men in the sample. Brogden (3) has demonstrated that there is no better set of linear functions of the predictor variables than these least-square equations for accomplishing this purpose. That is, a predetermined set of tests yields maximum allocation effectiveness when the predictor variables are given the least-squares regression weights as computed separately against each performance criterion. Thus, use of these full regression equations to compute predicted performance scores for each job and the use of these scores in an optimized assignment model will assure that the expected average performance of the assigned men has been maximized. On the other hand, while no other set of weights could make this particular set of predictor variables more effective, a particular variable may be contributing so little that its removal would have little effect.

Basic to the design of a simulation experiment is the generation for every individual of a vector of k independent random numbers; thus, any vector is an individual response basis in k dimensions. The numerical operations or functions which characterize different personnel policies are then applied to each of the vectors. Consequently, experiments designed to investigate system output under different policies can be based on the same entities or simulated individuals (i.e., the same vectors) for each of the policies. In other words, an identical sequence of random numbers can be generated for every policy so that the functions which define variations in assignment, enlistment, or retirement, say, are applied to numerical values whose stochastic components are identical.

One consequence of this way of proceeding is that sampling variability, which is a function of differences between the response bases of random numbers, occurs from person to person but not from policy to policy. Additional sources of random variation, of course, might be built into the functions which simulate policies. Even so, a relatively high component of response differences compared to stochastic sources of variation will be directly attributable to the effect of policy.

Difficulties occur with respect to statistical design, however, when observations corresponding to different policies are based on the same sample of subjects. To test the hypothesis that overall job performance is significantly greater under policy j than under policy k, an analysis of variance would require that estimates of error variation be independent for each policy, not correlated as when computed from the same set of subjects. A t-test for correlated means is appropriate when there are only two policies, but it becomes inappropriate when there are multiple policies or when a more complex factoring of experimental conditions is of interest.

Often, a multivariate analysis of variance is particularly suitable when repeated measurements are made on the same entities. Tests concerning group differences take into account covariation as well as variation between the dependent variates, and may lead to conclusions quite different from those which would have resulted if a series of univariate analyses had been performed. In the case of comparing policies based on the same individuals, however, the dependency between observations occurs across treatments, so that the estimates of error variation are not independent, as is required for both multivariate and univariate analyses of variance.

Wilks (4) has developed statistical criteria for testing equality of means, equality of variances, and equality of covariances for a multivariate normal population of k variables on the basis of a sample. The test for equality of means would seem appropriate when applied to k measures of system effectiveness which correspond to different allocation policies, but which represent the same individual. To make this test of no significant mean differences, however, equal variances and covariances for the k measures across different policies must be assumed. This condition would not be restrictive if interest were in establishing that the output measures of system effectiveness are parallel measures, a situation for which the Wilks criteria are well suited. Rarely, however, would equality of either variances or covariances be expected when observations are obtained from the complex series of operations which simulate personnel assignment procedures. In such case, equality could occur only if the same functions were applied to the random number vectors to simulate different policies.

A more subtle difficulty may complicate the choice of appropriate statistical tests for simulated observations. When all observations are independently sampled for an analysis of variance, it is the random fluctuation from treatment to treatment, as well as from individual to individual, which permits, under the null hypothesis, the determination of the two independent estimates of error variance necessary for testing the significance of treatment differences. When multiple observations are obtained from the same individual in the field situation, uncorrelated measurement error still occurs from treatment to treatment, even though estimates of it may not be directly obtainable. The choice of specialized statistical criteria such as the Wilks criteria when considering parallel tests may permit significance tests of treatment

differences. When, however, there is no error across treatments, as when observations simulating policy differences are generated from the same random numbers, statistical testing of treatment differences may require experimental designs different from those developed to provide inferences regarding empirical data. It may frequently be possible to take advantage of the fact that the experimenter using a simulation model knows many of the universe values of variables for which he could only make inferences if he were using empirical instead of computer generated data.

If research designs appropriate for empirical data are to be used, direct comparability of different policies within individuals may be sacrificed and simulation limited to observations which are independent over treatments. The extensive range of statistical designs associated with both multivariate and univariate analyses of variance could then be legitimately used in personnel system investigations using generated data. Once statistical significance of treatment differences is established, the policy differences can be estimated by repeating the simulation, but with entities generated from the same sequence rather than from independent sequences of random numbers. Direct comparison in which the individual serves as his own control of treatment effects is frequently not possible using actual observations. Such comparison may be considered a refinement characteristic of simulation experiments.

CRITERION CONCEPTS[1]

In describing computerized models, variables of three types may be considered. The first define the system. Values assigned to these variables are the "givens," the requirements or restraints contained within the system. The second are variables related to the policy or procedure being evaluated; these are modified to simulate different experimental effects. An optimal assignment process can be either type of variable; that is, optimization may be incorporated into the main framework of the system or it may represent one of alternate effects under study. The third type of variable is the criterion variable. It provides means of establishing the validity of the model, as well as of evaluating policy or procedural alternatives simulated within the model. Great care must be taken in defining the criterion index for the model not only to assure high degree of isometry with a criterion in the real system, but also to establish that the model criterion is related to the particular system criterion accepted by or at least acceptable to management. Often there

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[1] A separate SIMPO-I subtask is devoted to problems of criteria (SIMPO-I c: Development of Measures of System Effectiveness). Only preliminary considerations as they relate to entity-type models are given in this section.

are several possible criteria; therefore, consideration must be given to the possibility and advisability of defining some overall criterion of system effectiveness which would be a function of two or more of the possible criteria.

Any discrepancy between the model criterion index and the criterion variable in the real system may be cause to modify both the criterion index and the model. There is, of course, an alternative point of view. The model may be intended as a simulation of an ideal system. When this is the case, discrepancies between the model index and the system index merely indicate that the real system diverges from the ideal. The manner in which this divergence occurs should be understood in interpreting simulated results.

Modeling becomes more complex when there are several variables against which system effectiveness must be evaluated. Even when a model for personnel assignment is designed for very specific military applications, more than one of the following may need to be considered as criterion variables: reenlistment rate, selection ratio for promotion, quality of fighting force, shortages of particular types of personnel, and reduction in attrition of potential leaders.

Certain criterion variables, which may be called "restrictive criteria," are used only to identify characteristics which are prohibited in the system. Any policy which exhibits these undesirable characteristics is considered to lie outside the class of feasible policies. Multiple criteria such as these present no difficulty, since policies may be examined with regard to any number of restrictions. Other criteria, which may be categorized as "maximization criteria," are used to identify optimal policies. When there are multiple criteria of this type, the evaluation of system output may be particularly difficult. One approach is to investigate the tradeoffs among the criteria. Disproportionate increases in one criterion value may be found to accompany small decreases in another. Another approach is that of nesting optimizations. First, a hierarchy of criterion variables is established. Optimization of the system then proceeds variable by variable, starting at the highest priority. With each optimization, the feasible solution space is reduced, until a point is reached in which further optimization of the system cannot be accomplished. Results obtained for the higher priority optimization procedures are not affected by the successive solutions, however, and evaluation of the system can be based on the space of feasible solutions or on a function of the set of values obtained separately (and sequentially) for each of the objective functions.

GENERALIZED MODEL COMPUTER PROGRAM

The Statistical Research and Analysis Division, BESRL, has developed a computer program which serves to model characteristics common to a general class of personnel functions. The model is stochastic, and the

basic populations from which simulated individuals are randomly sampled is the multivariate normal, although non-random sampling resulting in non-normal distributions may also be simulated. The option of optimizing performance of a sample over multiple job categories is built into the model, and criterion indices can be related to the results of optimal allocation. Processing of manpower information may be simulated by use of linear transformations. To expand the model to contain more specific features, the computer program is written so that modifications can be easily incorporated.

Operations of the program are outlined in the flow diagram shown in Figures 1 and 2. Input of transformation matrices and parameters which determine characteristics of the system are represented in box 1. Defined are the number of samples to be simulated, the number of individuals in each sample, parameters which determine transformations to be performed on individual score vectors before and after allocation, job categories and quotas, and a starting vector for random number generation. Additional input may be read by subroutines written to expand the model (box 2).

Output consists of summary statistics computed over all individuals constituting a given sample (box 4) and also of the multiple replications which are customarily performed for a given experiment (box 5).

The simulation model (box 3) is shown in more detail in Figure 2.

The "general" part of the simulation model begins with the automatic generation of a vector of random normal deviates to represent each entity or individual (box 6 of the flow diagram); on this vector are performed a series of linear transformations of the form $\underline{v} = \underline{u}\ K + \underline{m}$ (box 7). K may be a matrix of least-square regression coefficients for obtaining performance estimates $\underline{v}$ from a set of predictor scores $\underline{u}$; $\underline{m}$ are the additive constants to yield estimates with specified means. A special purpose for which K is used in simulation studies is to transform random normal deviates, which have an expected covariance matrix equal to the identity matrix, into variates with an expected covariance matrix characteristic of the population under investigation. As indicated in Figure 2, the user specifies the series of linear transformations required to generate a particular sample by inputting the covariance matrices and vectors of mean values and then referencing these matrices on special transformation cards, which are input in the order of the transformations to be performed. The p cards define LOOP T for computations to be performed before allocation, and the q cards which follow define LOOP T for computations after allocation.

To perform non-linear transformations on the score vectors generated for each individual, or to perform any other operation to simulate characteristics of a more specialized system, specially written subroutines can be incorporated into operations under control of the main program. Modification and recompilation are required only for a short subprogram,

not for the main program. The subroutines are assigned integer names and are called by listing these integers in the order the subroutines are to be performed on the very cards which define the sequence of linear transformations (i.e., parameters within LOOP T).

The parameter subroutines are also used to determine whether the scores being generated for a given individual are consistent with sample characteristics defined for a particular investigation. As the operations specified on each transformation card are completed, an index, which may have been set to reject a given individual by any of the subroutines, is automatically sensed by the main program (box 9 of the flow diagram). Thus, tests for individual acceptance or rejection may be performed repeatedly and at any stage in the computations.

The result of the sequence of operations specified on the transformation cards is the construction of an N x c matrix of performance measures; the c columns correspond to job categories under investigation, and the N rows represent the individuals in the sample. Based on this matrix, each of the N individuals is optimally assigned to one of the c jobs in such a way that required quotas for the different jobs are met (box 12).

After assignment, the response vectors for the N individuals are regenerated to compute statistics that are functions of the job to which each individual is assigned (box 13). These are the computations specified on the second set of transformation cards previously input and serving to redefine LOOP T. Additional parameter subroutines are included if special computations are required. (Allocation averages and frequency distributions for jobs to which men are assigned are examples of statistics used in summarizing kinds of simulation, and general routines have been prepared for computation of these statistics.) In order for simulated performance measures to represent the same individuals both before and after optimal allocation, the starting vector of random numbers is re-initialized after allocation.

REPRESENTATIVE APPLICATIONS

The purpose here is to describe typical problems for which this simulation model is well suited. Among the series of experiments which motivated development of a general program was a study by Sorenson (5) on the use of full regression equations versus aptitude area scores for the optimal allocation of enlisted men. The eleven tests of the Army Classification Battery are designed to predict performance in different job areas. However, the operating Army personnel system is basing predictions on computationally simplified composites of only two tests. The purpose of the simulation was to estimate the performance gain using the full set of measures compared with the abbreviated set.

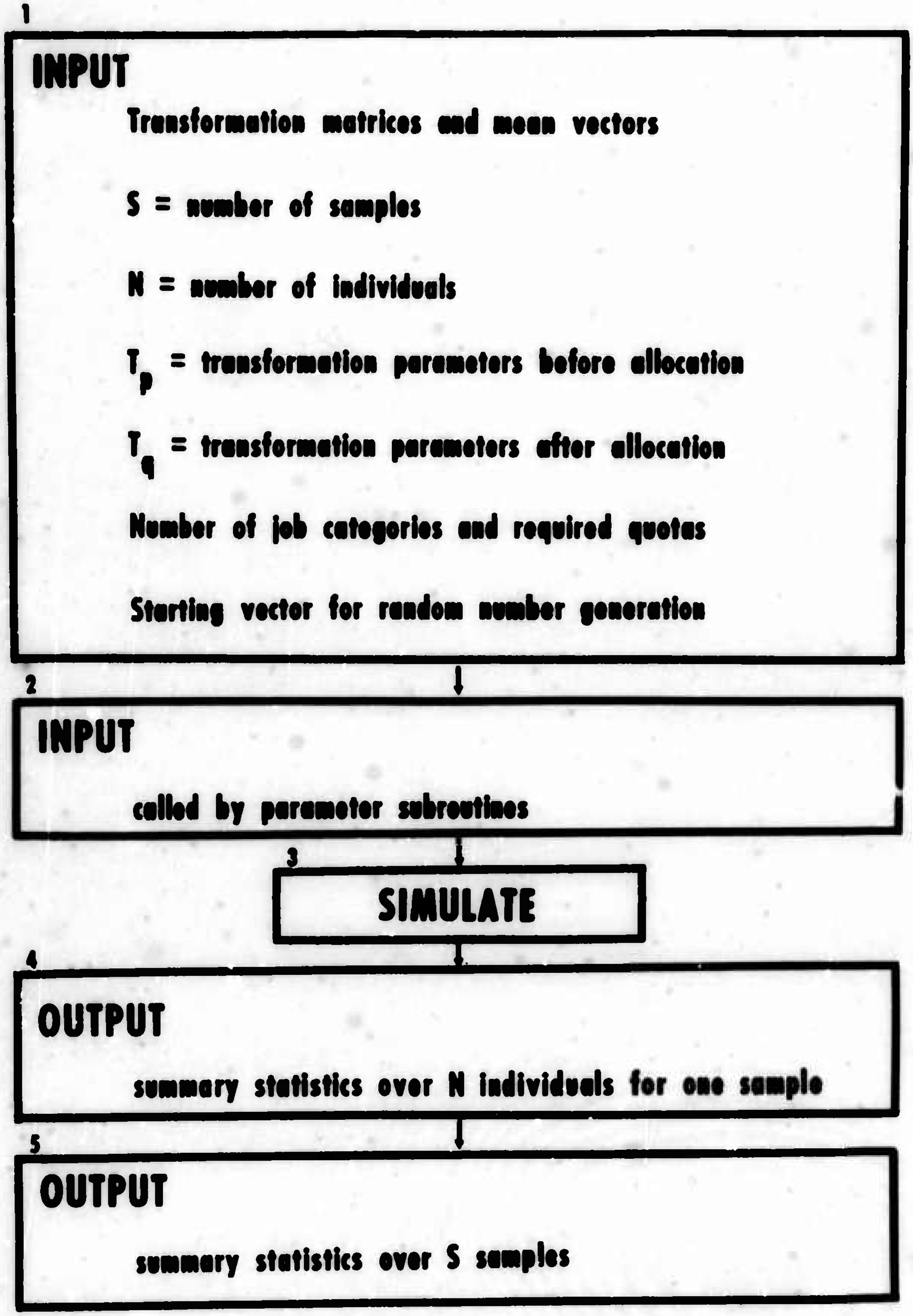

Figure 1. Flow diagram for general computer model

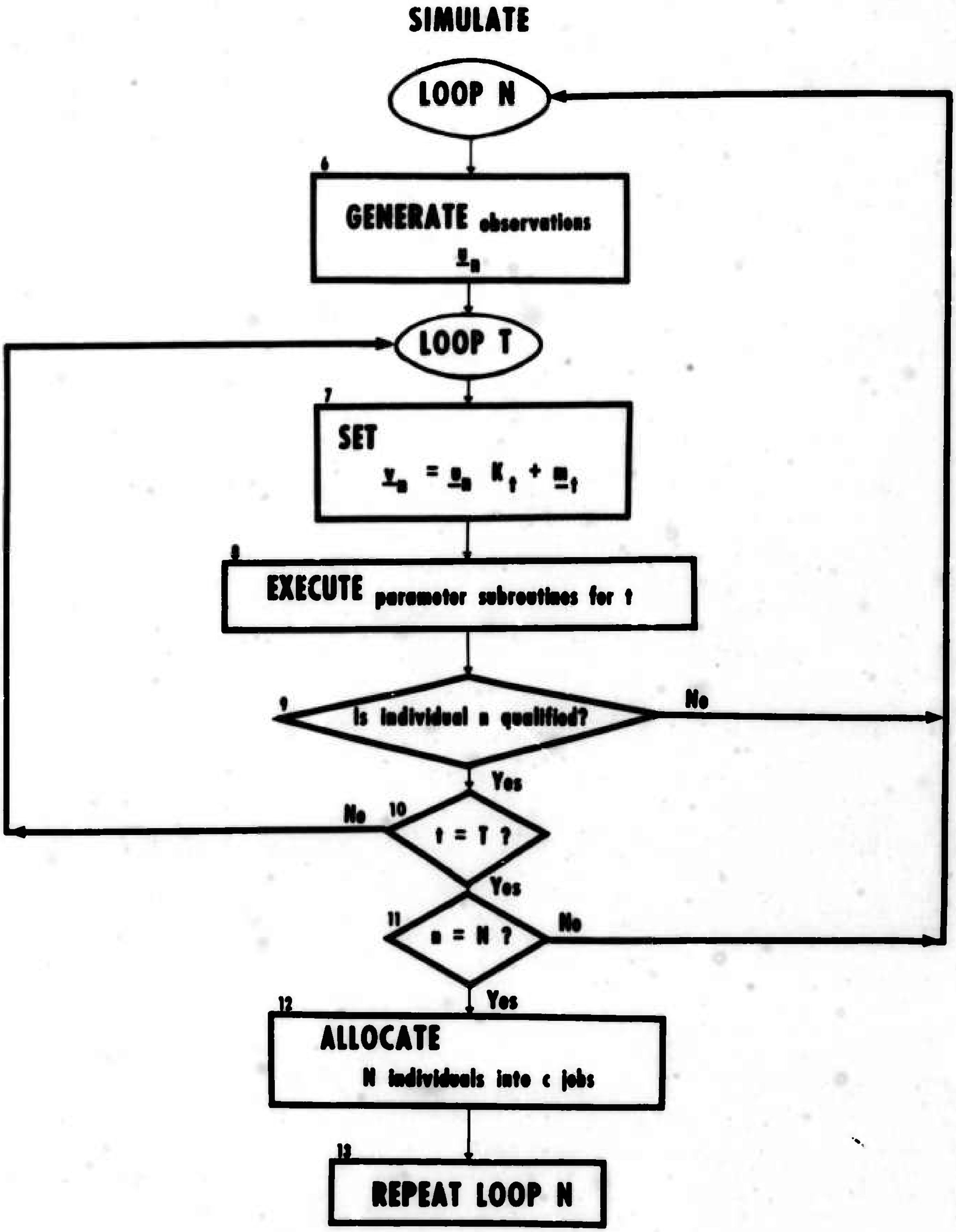

Figure 2. Simulation of personnel policies and procedures

Performance estimates obtained by each of the two methods were used to allocate optimally samples of men into eight job areas such that prescribed quotas were met. The difference between the performance averages over simulated samples after optimal allocation provided a measure of differential effectiveness of the two methods of combining predictors. The gain over random allocation was roughly doubled by the use of regression equations.

Results for the published study were obtained from a specially written program, but re-analysis could now be performed much more simply because of the availability of the general program. The two kinds of performance estimate would be constructed automatically and simply within the program by performing an appropriate sequence of linear transformations on the vector of random numbers generated to represent each individual. The user would need only to input the necessary transformation matrices as data and to specify on parameter cards the order in which they are to be used.

As example of the type of simulation which would require the use of specially written parameter subroutines as well as the automatic features of the general program was reported by Sorenson at the 1966 Army Operations Research Symposium. A specially written program which did not have the more general properties of the entity model was used to obtain these results. The purpose of the simulation was to examine the effect of metric changes on the results of optimal allocation. In using the general program, performance estimates for each individual on different job categories would be constructed by linear operations similar to those used for the study just described. Each set of observations would then be modified to represent eight different metrics. For example, criterion estimates with an expected mean of 100 and standard deviation of 20 would be converted to two-digit integer scores ranging from 0 to 99 by subtracting 50 and truncating. One-digit scores from 0 to 9 would be formed by subtracting 50, dividing by 10, and truncating. Ordinal scales would be constructed by ranking individuals within jobs. These modifications would be performed by specially prepared parameter subroutines. After control was returned to the main program, an optimal allocation procedure would be performed for each type of metric, along with the computation of measures of overall performance from which the effect of the various metrics could be evaluated.

The parameter subroutines are especially useful when information is needed concerning the effect on optimal assignment of a change in the minimum requirements for entry into service. For example, scores on predictor tests (The Armed Forces Qualification Test and tests of the Army Classification Battery) can be generated to characterize samples from the mobilization population. These scores can in turn be differentially sampled with respect to the AFQT variable, to depict the reality that the proportion of the source population which actually enters military service is omitted from subsequent analysis, but simulation is repeated

until a specified number meet the AFQT requirement. An example of one such policy is to simulate a probability of omitting 60 percent of those who score 91 to 100 on the AFQT variable, 45 percent who score from 71 to 90, and 30 percent who score from 30 to 70. The selection could be continued by computing performance estimates from the predictor scores and further restricting the sample to men who score higher than 90, say, for two or more job categories. Studies of this kind have been used to recommend policies to the Army concerning changes in input requirements for enlisted men in the context of a particular deferment policy.

One particular application involves obtaining estimates of overall job performance as a function of various restrictions on the incoming population at a fixed point in time. For a different type of study, interest might be in overall performance when various restrictions are made on personnel as they operate within the system over an extended period of time. That is, performance at different stages of experience is simulated. In the field situation, samples constructed on the basis of training experience are usually composed of different sets of individuals because of difficulty of doing follow-up studies on the same men. In a simulation study, however, performance for the same individual can be followed through the complete time cycle. This follow-up is accomplished by first inputting transformation matrices which yield expected means, variances, and covariances for men who have t_1 months of experience, t_2 months of experience, up to t_k months of experience. The vectors of random numbers generated for each individual are then post-multiplied by these matrices, maintaining the same random numbers each time a given individual is represented over time.

At the start of the simulation, individuals in a sample are optimally assigned over c jobs on the basis of criterion performance. During the first t_1 months, each of the N individuals is examined for possible loss from the system. This loss may be a function of an individual's estimated job performance, simulated events occurring within the system, a random process which determines that near to p percent of the sample will be lost, or some combination of these variables. Functions which determine loss are added to the program as parameter subroutines and may differ for the different job categories and for the number of months an individual has served.

For each individual remaining in the system, new performance measures appropriate to his job assignment and the length of time he has spent in the system are simulated. To replace men lost to the system, new random numbers are generated and transformed to expected values for an inexperienced population. Assignment to different job categories is performed such that expected performance of the new sample is optimal and job quotas reduced by loss are restored to their original values.

At the end of each point in time, t_i, the effectiveness of the system is evaluated. The evaluation may be as simple as computing the average measure of job performance for the different job categories; or it could involve a fairly complex function of the performance of crew members where a weapon system is involved. Simulation then proceeds from time t_i to time t_{i+1} by again testing observations for the N individuals for loss or retention in the system and by generating new observations to represent enough inexperienced personnel to fill the losses. At the end of the k-th simulation run, representing the passage of t_k months, simulated observations will represent individuals with time in service ranging from zero months to full length of the tour.

With this type of simulation, quality of predicted performance in the system can be examined as the proportion of experienced personnel in the system increases. In addition, the rate or change in rate at which men are lost from the system can be related to system performance. Experiments which investigate constant loss rates over all jobs may be specialized to examine varying patterns of loss rates for different jobs. Research of a more technical nature might involve comparison between different approaches to optimal allocation. Optimal assignment of the incoming sample can be based only on performance estimates of men in that sample. A different approach would take into account performance estimates of the total sample, including the experienced personnel, when determining initial assignment of incoming personnel.

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APPENDIX

FLOW DIAGRAM AND MANUAL FOR THE GENERAL COMPUTER PROGRAM FOR SIMULATION EXPERIMENTS

A detailed description of the general simulation program with an expanded flow diagram (Figure A-1) is presented in Section I. Section II is a manual for use of the program. Included in the manual are specifications for input and requirements for programming parameter subroutines.

SECTION A-I

THE COMPUTATION PROCEDURE

The program operates in four parts: I, input and initialization required before sample generation; II, simulation of individual response vectors, optimal allocation, and regeneration of response vectors; III, computations and output based on the ν individuals in a sample, plus initialization required for generation of a new sample; and IV, computations and output based on all samples generated. Reference to the flow diagram of Figure A-1 may clarify the sequence of operations.

To perform operations consistent with the four parts of the main program, four entry points must be written into every parameter subroutine. To transfer control to parts I, III, and IV, the main program automatically calls all subroutines listed on the transformation cards in order of increasing size of integer names assigned to the subroutines. (During execution of part II, the subroutines are called in the order listed on the transformation cards.) Dummy instruction ("returns") are written into entries for any of the four parts not used by a subroutine.

INPUT OPERATIONS

Operations which constitute Part I consist of the input of transformation matrices and associated mean vectors (box 1), input of the vector of starting numbers to initialize random number generation (box 2), input of the number of individuals to be simulated and other parameters defining characteristics of each sample (box 3), input of the transformation cards (box 6), and σ, the number of samples to be simulated (box 7). To make it convenient to generate δ different sets of samples during one computer run, each set being defined by different lists of transformation cards, the parameter δ is input (box 4). All transformation matrices required for the δ sets of samples are input simultaneously under control of the first part of the program (box 1). Any of these matrices may be used for any of the δ different problems by entering an integer which corresponds to the order in which the given matrix was input into the appropriate column of a transformation card.

The input of parameters of data required for execution of any of the parameter subroutines is represented by box 8. This input is called in order of increasing size of the integer-named subroutines. Any additional initialization required for subsequent operation of the subroutines is also performed within this first entry.

SIMULATION OPERATIONS

Part II of the program, simulation of individual response vectors, optimal allocation, and regeneration of the response vectors, is

illustrated in boxes 9-27. To begin response simulation (box 9), the starting vector $\underline{A}_{sn}$, which controls the generation of random numbers, is set equal to the vector input to represent the first individual of sample 1 ($\underline{A}_{11}$ in box 2). This vector automatically changes as random numbers are generated for each individual (boxes 21 and 27). Box 16 refers to the case where the responses being generated for individual n have been found unacceptable by one of the parameter subroutines; consequently, another vector, $\underline{A}_{sn'}$, is generated from which a new set of scores representing the n^{th} individual can be constructed.

Optimal allocation over the ν individual response vectors is performed at the center of the simulation operations (box 22). Regeneration of individual response vectors then begins at box 10. To insure that the same set of individual responses is generated before and after allocation, the starting vector for individual 1 of sample s, $\underline{A}_{s1}$, is saved for the re-initialization shown in box 23. The starting vector which defines the beginning of each sample is automatically printed out by the main program (box 10) so that simulation can be continued from any point of unanticipated termination of production.

Linear transformations and parameter subroutines specified by the first τ_1 transformation cards are performed on each individual response vector of random normal deviates (boxes 13 and 14) until the matrix consisting of c performance measures for ν individuals has been constructed. Execution of the $\tau_1 + \tau_2$ transformation cards is under control of the index t, as shown in boxes 17-19, 21, 23-25, 27. Box 15 illustrates the feature of examining the qualifications of each individual every time the computations specified on a transformation card are completed.

COMPUTATIONS AND OUTPUT

Parts III (box 28) and IV (box 31) represent the automatic calls to the parameter subroutines to perform operations over the ν individuals in a sample and then over the σ samples respectively. The final loop $\underline{d}$ determines whether a new set of transformation cards will be input (at box 6) to define additional samples. The new samples will be based on the same set of parameters (ν, Π, ρ, boxes 1-4) which defined the previous samples, with differences occurring only as specified on the new transformation cards. Note that the starting vector which begins the generation of random numbers is reset to $\underline{A}_{11}$ (box 9), so that equivalent sets of individual responses will be generated for each of the δ sets of samples.

1

START

INPUT:
Transformation matrices and associated mean vectors.

2

INPUT:
Starting vector $\underline{A}_{11}$ to begin sequence of random number generation for sample 1, individual 1.

3

INPUT:
ν = the number of individuals in each sample.

π = the number of random normal deviates constituting the initial response vector generated for each individual

ρ = the number of job categories

Required quotas $\mu_1, \mu_2, \ldots, \mu_\rho$ for each of ρ jobs; $\sum_{i=1}^{\rho} \mu_j = \nu$

4

INPUT:
δ = the number of different sets of samples to be simulated, with each set defined by the input of a different sequence of transformation cards.

(1)

(1)

5

$d = 1$

Loop $\underline{d}$

6

INPUT:
$\tau_1 + \tau_2$ transformation cards, each defining a transformation t and listing k_t subroutines to be performed on the π random normal deviates generated for every individual. Prior to optimal allocation, $t = 1, 2, \ldots, \tau_1$. Post-allocation, $t = \tau_1 + 1, \tau_1 + 2, \ldots, \tau_1 + \tau_2$.

7

INPUT:
σ = the number of independent samples to be simulated, as defined by ν, π, ρ, $\underline{A}_{11}$, and each set of transformation cards.

8

INPUT:
Parameters or data required for execution of any of the k_t subroutines associated with each t, $t = 1, 2, \ldots, \tau_1 + \tau_2$.

In addition, perform any initialization required for subsequent execution of these subroutines at entries II, III, IV. In other words, execute the $k_{\tau_1} + k_{\tau_2}$ subroutines at entry I.

(2)

Figure A-1. Flow diagram of General Program for Conducting Optimal Allocation Experiments

PART I - Input Operations

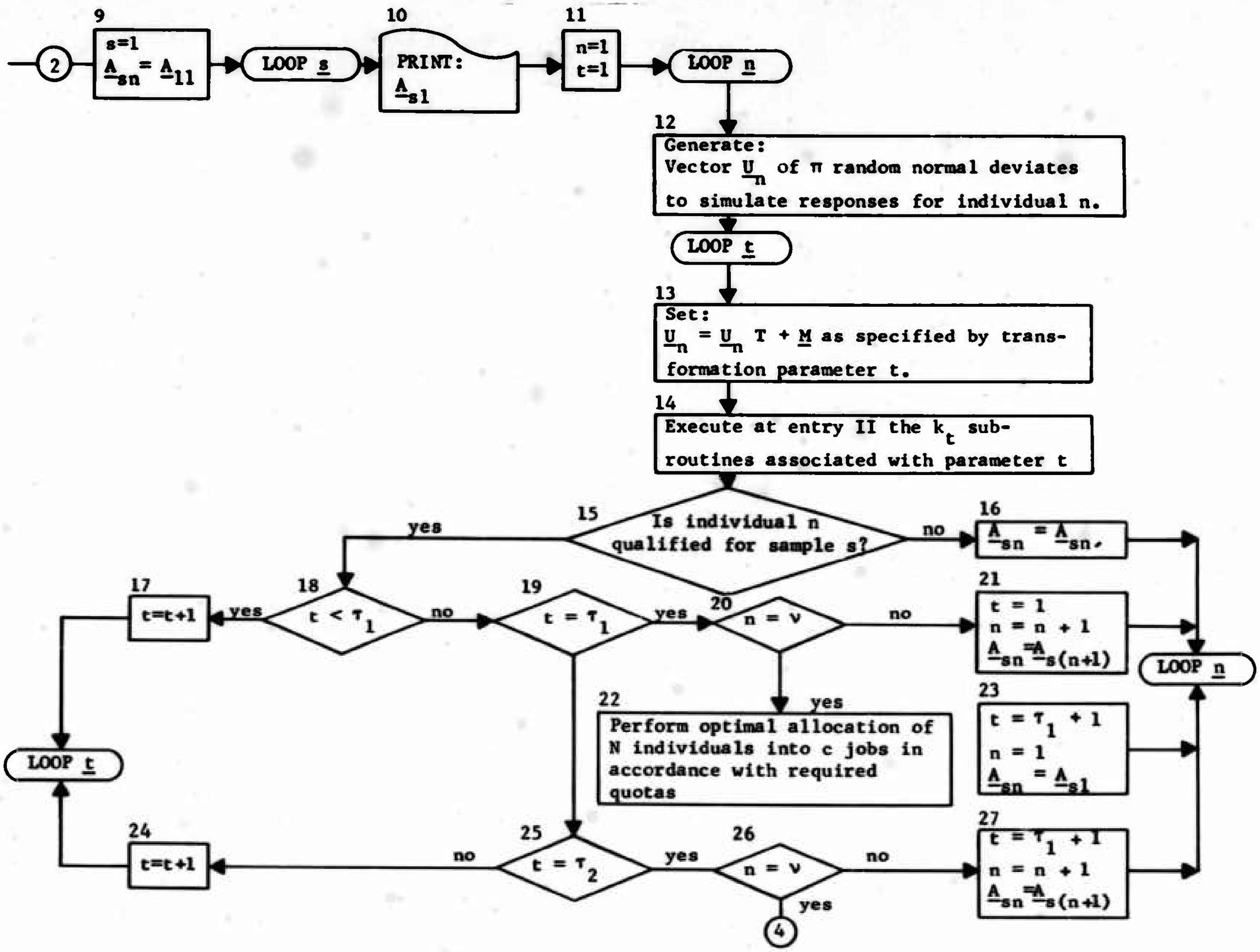

Figure A-1. (continued) PART II - Simulation Operations

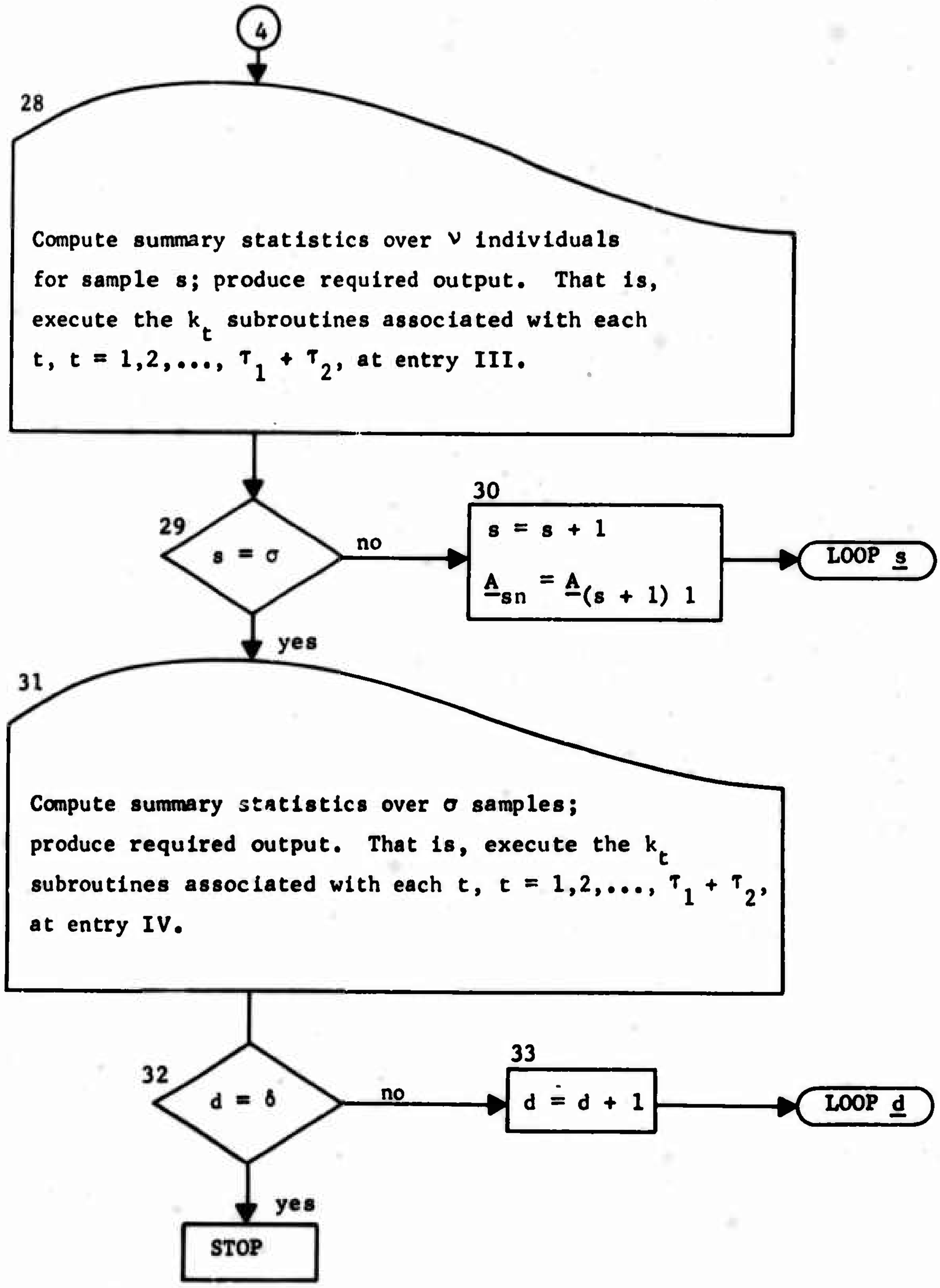

Figure A-1. (continued)
PART III - Computations and Output (ν individuals) and
PART IV - Computations and Output (σ samples)

SECTION A-II

MANUAL FOR USE OF GENERAL COMPUTER PROGRAM FOR SIMULATION EXPERIMENTS

INPUT FORMAT

iter 1   i j (Format 1XA6, I4, I2)

i is an integer which occupies columns 8-11 and specifies the number of complete sets of data and parameters to be input. To debug new subroutines, detailed print-out of individual score vectors may be obtained by setting j = 1, columns 12-13; otherwise, j = 0.

TRANSFORMATION MATRICES

1j, 2j,...,ij,... (Format 10(I1,I1,A1))

Beginning in column 1, a two-digit integer ij, which may be followed by a comma, is listed for every matrix input. i = 1 for the first matrix input and is increased by one for each successive matrix; the maximum i = nmat ("nmat" is a parameter set within the main program to determine the total number of transformation matrices to be input). If a vector of means associated with a given transformation is to be input, j = 1; otherwise, j = 0.

$\alpha\beta$ (Format 2I2)

MATRIX X   (Format 1X, 9A8)

Transformation Matrix (Format 9F8.4)

For every ij listed, one card is input defining the order of the matrix, followed by a second card containing any alpha-

numeric name for the matrix, followed by the matrix itself. α (columns 1-2) is the number of rows, and β (columns 3-4) is the number of columns. Elements of the matrix are input row by row with the format 9F8.4.

MATRIX XM (Format 1X, 9A8)

Means Following the transformation matrix associated with a given ij, if j = 1, an additional alphanumeric card identifies the vector of means. The means begin in the next card with format 9F8.4.

Starting Vector

The γ = 24 octal digits which begin the generation of γ independent sequences of random numbers, are input on 3 cards with format 9Ø8.

ν π ρ (Format I4, 2I2)

ν (columns 1-4) is the number of individuals in the sample.

π (columns 5-6) is the number of independent random normal deviates generated for each individual to initiate the simulation of ρ performance measures.

ρ (columns 7-8) is the number of job categories on which optimal allocation is to be based.

μ_1 $\mu_2 \cdots \mu_\rho$ (Format 14I5)

Required quotas for each of ρ jobs: $\sum_{j=1}^{\rho} \mu_j = \nu$.

iter 2 = δ (Format 1XA6,I4)

δ specifies the number of complete sets of parameter cards and data which are to follow, all of which will be controlled by the set of cards previously input.

TRANSFORMATION CARDS

τ_1 τ_2 (Format 2I2)

τ_1 cards will follow specifying transformations and subroutines to be performed on the vector of π normally distributed standard scores generated for individual n at working storage $\tilde{\underline{U}}$, preceding optimal allocation. The next τ_2 cards specify the transformations and subroutines to be performed on the same individual response vector regenerated at $\tilde{\underline{U}}$ following optimal allocation.

The post-multiplication of a response vector located at working storage $\tilde{\underline{U}}$ (or $\tilde{\underline{V}}$) by any transformation matrix input (T_I), the addition of the vector of means associated with the given transformation ($\underline{M}_I$), and the storage of the results in working storage $\tilde{\underline{V}}$ (or $\tilde{\underline{U}}$) can be specified on any of the $\tau_1 + \tau_2$ transformation cards by the following codes:

12,I $\Longrightarrow$ $\underset{1\times\beta_I}{\tilde{\underline{V}}} = \underset{1\times\alpha_I}{\tilde{\underline{U}}} \; \underset{\alpha_I \times \beta_I}{T_I} + \underset{1\times\beta_I}{\underline{M}_I}$

21,I $\Longrightarrow$ $\underset{1\times\beta_I}{\tilde{\underline{U}}} = \underset{1\times\alpha_I}{\tilde{\underline{V}}} \; \underset{\alpha_I \times \beta_I}{T_I} + \underset{1\times\beta_I}{\underline{M}_I}$

Different T_I and $\underline{M}_I$ are referenced by setting I to any integer from 1 to nmat corresponding to the order in which the transformation matrices are input. If no vector of means has been input for T_I, $\underline{M}_I = 0$. Multiplications are performed on only the first α_I elements of $\tilde{\underline{U}}$ (or $\tilde{\underline{V}}$), and the result changes only the first β_I elements of $\tilde{\underline{V}}$ (or $\tilde{\underline{U}}$); α_I and β_I are the number of rows and columns of T_I.

ν scores can be relocated from one working storage area to the other by setting I = 0. That is,

12,0 ==> $\underset{1\times\nu}{\underline{\tilde{V}}} = \underset{1\times\nu}{\underline{\tilde{U}}}$

21,0 ==> $\underset{1\times\gamma}{\underline{\tilde{U}}} = \underset{1\times\nu}{\underline{\tilde{V}}}$

Following allocation over jobs $j = 1, 2, \ldots, \rho$, a statistic, which is a function of the job j to which each individual is assigned, may be computed and stored in x ($\underline{\tilde{W}}(49)$). That is,

10,I ==> $\underset{1\times1}{\tilde{x}} = \underset{1\times\alpha_I}{\underline{\tilde{U}}} \; \underset{\alpha_I\times1}{T_{Ij}} + \underset{1\times1}{m_{Ij}}$

20,I ==> $\underset{1\times1}{\tilde{x}} = \underset{1\times\alpha_I}{\underline{\tilde{V}}} \; \underset{\alpha_I\times1}{T_{Ij}} + \underset{1\times1}{m_{Ij}}$

where $\underline{T}_{ij}$ is the j^{th} column of T_I and m_{Ij} is the j^{th} element of $\underline{M}_I$. If no transformation matrix is to be used, the j^{th} element of $\underline{\tilde{U}}$ (or $\underline{\tilde{V}}$) can be relocated in $\tilde{x}$ by setting I = 0:

10,0 ==> $\tilde{x} = \tilde{u}_j$

20,0 ==> $\tilde{x} = \tilde{v}_j$

PARAMETER SUBROUTINES

To perform additional kinds of computations on scores in $\underline{\tilde{U}}$, $\underline{\tilde{V}}$, or $\tilde{x}$, a list of subroutines may follow the transformation codes on any of the $\tau_1 + \tau_2$ transformation cards. Each subroutine is equated to some integer between 1 and 99 and is listed in the order of required execution. Beginning in column 5 with format 5(A1,I2), each subroutine is introduced by a comma, with the following integer name occupying two

columns. As many as 5 subroutines may be referenced on a given card. To illustrate, suppose the post-multiplication of scores in $\tilde{\underline{U}}$ by the second matrix input is required, to be followed by the execution of subroutines 3, 98, and 1, which have been especially written to operate on the result in $\tilde{\underline{V}}$. The transformation card would appear as:

12,2,03,98,01

During simulation of scores for a given individual, a reject parameter is evaluated each time the processing defined by a transformation card is completed. Depending on the value of this parameter, scores for the individual are either retained for further processing or are treated as inappropriate for a given sample and eliminated. If it is desired to subdivide a list of subroutines so that the reject parameter will be evaluated after the execution of only one or two, say, of the subroutines, additional transformation cards defining the subroutine subsets are inserted, but with columns 1, 2, and 4 set to zero. To illustrate, suppose the v scores in $\tilde{\underline{V}}$ are to be transferred to $\tilde{\underline{U}}$, to be followed by execution of subroutines 3, 98, and 1, written to operate on scores in $\tilde{\underline{U}}$. The reject parameter, modified by subroutines 3 and 1, say, is to be evaluated after the execution of 3 and 1. The appropriate two transformation cards would appear as:

21,0,03

00,0,98,01

NUMBER OF SAMPLES

iter 3 = i (Format 1XA6,I4)

i is an integer which occupies columns 8-11 and specifies the number of independent samples to be simulated as defined by all previous parameter cards input.

INPUT CALLED BY SUBROUTINES

The input of parameters and data may be required for the execution of subroutines listed on the transformation cards. Input called by different subroutines is arranged by increasing order of the integers which name the subroutines.

ADDITIONAL REQUIREMENTS FOR PROGRAM USE

The feature of specifying alternative sequences of linear transformations and subroutines as parameters may be considered a compiler for individual response simulation. Unfortunately, incorrect use of this part of the program will not produce simple error diagnostics, but may generate meaningless results. To insure that the same individuals are accepted into the sample before and after allocation, the user must specify the correct sequence of transformations and subroutine calls. In addition, care must be taken to maintain the correct order of simulated scores which represent tests of interest. For example, the transformation $\underline{V} = \underline{U}\,T$, which is specified on a transformation card by equating an integer to the order in which the appropriate matrix is input, will operate only on the first α elements in the first working storage area $\tilde{\underline{U}}$ and will replace

only the first β elements of the second working storage area $\tilde{V}$; α and β are the number of rows and columns, respectively, of the transformation matrix T. Scores, then, which are to be modified by reference to parameter subroutines, but not by post-multiplication by one of the transformation matrices, must be represented by elements subsequent to those altered by linear transformations. Accuracy of results can be checked by setting the special debug parameter, which will produce detailed print-out of computations intermediate to the final results.

DEFINITION OF DIMENSION STATEMENTS AS LISTED IN THE COMPUTER PROGRAM

KO(N,LC): Matrix of fixed-point performance estimates for N individuals on each of LC jobs. Currently (**January 1968**), N = 1000 and LC = 8.

IROW(N): Vector containing the job j, j = 1, 2, . . . , LC, to which each of N individuals is assigned.

KQ1(LC), KQ2(LC):

Storage areas for the required quotas for each of LC jobs.

Z(AREA): Storage area for all transformation matrices, thus requiring that

$$\text{AREA} \geq \sum_{m=1}^{\text{NMAT}} (\text{NA}_m \times \text{MA}_m),$$

where the order of each matrix input is NA (rows) x MA (columns), and the total number of matrices input is NMAT.

Currently, AREA = (23 x 23) + (11 x 8) + (11 x 8) = 705.

ZM(TMA): Storage area for means associated with each transformation matrix, with $\text{TMA} \geq \sum_{m=1}^{\text{NMAT}} \text{MA}_m$.

Currently, TMA = 23 + 8 + 8 = 39.

V(S)[1], V(S), W(2S + 1), with U(1) = W(1) and V(1) = W(S + 1)

Working storage areas used for simulating a maximum of S individual responses.

Currently (January 1968), S = 24.

IISV(S), ISV(S), JSV(S):

Areas used for storing the starting vector of S octal digits called by subroutine RAND.

VFOR(9)

Area used for input of variable format.

IS(NTRAN), JS(NTRAN,5), JN(NTRAN), KN(NTRAN,6), LIST(NSUB):

Storage areas used for setting up the sequence of transformations and subroutines used in simulating responses for each individual. NTRAN is the maximum number of transformation cards which can be input for a given simulation experiment. NSUB is the maximum number of different parameter subroutines which can be listed on transformation cards for the experiment.

Currently, NTRAN = 8 and NSUB = 10.

NA(NMAT), MA(NMAT), NT(NMAT):

Areas used for addressing transformation matrices and associated vectors of means. Currently, NMAT = 3.

For the most efficient utilization of computer space, the main program can be recompiled so that N, LC, AREA, TMA, and NMAT are consistent with requirements for specific

---

[1] The storage area represented here by S is represented in the description of the program by γ.

projects. The statement "NMAT = 3", which is within the first part of the main program, will also have to be changed. Changes in S, NTRAN, and NSUB will not result in appreciable saving of space. If changes are required for S, NTRAN, and NSUB, additional changes must be made in statements of the main program.

PROGRAMMING REQUIREMENTS FOR PARAMETER SUBROUTINES

Any subroutine written to handle computations specific to different projects must be associated with an integer name, and the first parameter of every subroutine must be "JSUB". Thus, "SUBROUTINE SUB J (JSUB, ...)", when J is any integer, would appropriately begin a subroutine. In addition, the first statement of any subroutine must be "GO TO (a, b, c, d), JSUB", a, b, c, and d not all necessarily different.

All subroutines listed on the transformation cards are automatically called in four different parts of the main program. Corresponding to each part, JSUB is set to 1, 2, 3, or 4 to permit execution of different types of subroutine operations.

Before beginning response simulation for any sample of ν individuals, the main program sets JSUB = 1 and transfers control to statement a of each subroutine in order of increasing size of the integers naming the subroutines. Any initialization or calls for input of data or parameters required for subsequent operations must be written into this "part a" of each subroutine. If no such initialization is required, statement a will be a "RETURN".

During the simulation of individual score vectors in the second part of the main program, JSUB = 2; for each individual in every sample, control passes to statement b of each subroutine according to the order transformations and subroutines are listed on the transformation cards. The main function of subroutine sections beginning at statement b, then, will be to operate on scores in working storage areas $\tilde{U}$, $\tilde{V}$, or $\tilde{x}$ or to construct KO, the $\nu \times \rho$ matrix of scores used by subroutine OTT for optimal allocation.

After all computing to be performed on ν individuals has been completed, the main program sets JSUB = 3, and control is transferred to statement c of each subroutine, again in order of increasing size of the integers naming the subroutine. "Part c" of each subroutine must be written to perform any summary computations based on all ν individuals for the sample just completed, and to perform any initialization required for generating the next sample. If no such computations are required, statement c must be a "RETURN".

When simulation of the total of σ samples has been completed, the main program sets JSUB = 4, and control is transferred to statement d of each subroutine, again according to the order of the subroutine numbers. Any summary computations or output based on the completed set of σ samples or any initialization required before parameters defining a new set of σ samples are input must be written beginning at statement d. Otherwise, statement d must be a "RETURN".

MODIFICATION OF SUBROUTINE EXSUB

The call statement for any of the parameter subroutines listed on the transformation cards occurs in the executive subroutine. Each time, then, that a new subroutine is prepared for a specific project, "Subroutine EXSUB" must be recompiled.

At the time for execution of any of the subroutines listed on the transformation cards, the main program automatically sets a parameter "KM" within "EXSUB" to the integer name of the subroutine. Any test which recognizes that KM equals this integer name, J, say, and is followed by the execution of a statement calling "SUBROUTINE J", may be written into the executive routine. One convenient method would be to extend the length of the computed go-to statement (currently, "GO TO (1,2,3,4,5), KM"), making the j^{th} parenthesized integer equal to J such that, when KM = J, control will be transferred to statement J, and subroutine J will be executed. Care must be taken to insert any new subroutine call statements to operate within the range of the do-loop which terminates at statement (currently labeled) 25.

All regions likely to be referenced by specific subroutines are in the COMMON area for both the main program and EXSUB. Those regions most likely to be needed as parameters in any of the subroutines are defined as follows:

KO — the $\nu \times \rho$ matrix of fixed-point scores used by subroutine OTT for optimal allocation.

U and V — working storage areas beginning at $\underset{\sim}{\tilde{W}}(1)$ and $\underset{\sim}{\tilde{W}}(25)$, respectively, used for the post-multiplication of an

individual score vector by a transformation matrix and possible subsequent addition of a mean vector.

LC (equivalent to ρ)

a single score selected from the ρ scores simulated for a given individual to correspond to j, $j = 1, 2, \ldots, \rho$, the job to which the individual is assigned.

N the number of individuals in a given sample.

I index for the number of individuals: $I = 1, 2, \ldots, N$

ITER3 (equivalent to S)

the number of samples of "N" individuals to be simulated for each set of transformation cards input.

IT3 index for the number of samples: IT3 = 1, 2, . . . , ITER3

JECT parameter set by any subroutine and sensed by the main program to determine whether a given individual is qualified for the sample being simulated. If JECT = 1, the individual is accepted; if JECT = 2, the individual is rejected. The main program initializes JECT to 1.

DESCRIPTION OF EXISTING SUBROUTINES

The subroutines which are listed below have been written for generalized application. Subroutines limited to use on specific projects are not described.

SUBROUTINE SUB 1 (JSUB, KO, W, I, LC)

SUB 1 rounds the LC floating point scores simulated for individual I and located at $\tilde{\underline{U}}$ to the nearest integers. These scores are then stored in the I^{th} row of the fixed point matrix area $\widetilde{KO}$ used for optimal allocation by SUBROUTINE OTT.

SUBROUTINE SUB 2 (JSUB, KO, W, I, LC)

SUB 2 rounds the LC floating point scores simulated for individual I and located at $\underset{\sim}{V}$ to the nearest integers. These scores are then stored in the I^{th} row of the fixed point matrix area $\widetilde{KO}$ used for optimal allocation by SUBROUTINE OTT.

SUBROUTINE SUB 3 (JSUB, W, N, IT3, ITER3)

SUB 3 computes (1) the sum and (2) the mean value in $\tilde{x} = \underset{\sim}{W}(49)$ over N individuals and (3) a summary mean of the value in $\tilde{x}$ over ITER3 samples of N individuals. This subroutine was written to compute the allocation sum and average for each sample of N individuals and the allocation average for all samples combined. $\tilde{x}$ is set to the performance estimate on the job to which each individual has been assigned.

SUBROUTINE SUB 4 (JSUB, W, I, N, IT3, LC, IROW)

SUB 4 computes the frequency distributions of scores located in $\tilde{x} = \underset{\sim}{W}(49)$ for each of the job categories to which men are assigned. Means and standard deviations for scores in each job category are computed for each sample of N individuals. Frequency distributions, means, and standard deviations are also computed by job category for all samples combined.

Four cards are required input.

Card 1: identification card for labeling frequency distributions, with format (9A8).

Card 2: parameters which determine the scale of the distributions, with format (2F8.4, I4)

Z = length of each interval

SZ = lower bound of first interval

NZ = number of intervals

Card 3: variable format for printing LC floating point numbers (means, standard deviations, and interval midpoints); e.g., (15F8.4).

Card 4: variable format for printing LC fixed point numbers (frequencies); e.g., (15I8).

SUBROUTINE SUB 5 (JSUB, U, I, N, IQ)

Compute means, standard deviations, and correlation matrix for IQ variables in U over N individuals.

SUBROUTINE SUB 6 (JSUB, V, I, N, LC)

Compute means, standard deviations, and correlation matrix for LC variables in V over N individuals.

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13. ABSTRACT

The entity simulation model described in this publication is an initial product of the operations research efforts conducted by the Statistical Research and Analysis Division, BESRL under SIMPO-I Task. The model was designed for integration into the more generalized SIMPO-I simulation package for evaluation of personnel and manpower policy alternatives across the Army's major personnel functions. The entity model concentrates on the procurement, selection, and allocation aspects of the personnel system. The SIMPO-I, when completed, will consist of a relatively comprehensive computerized model of the Army personnel subsystem--incorporating a simulation model and a library of computer programs. Other modules to be developed, having appropriate interfaces with the entity module, will be concerned with such personnel functions as distribution, tour rotation, promotion, and training. Representative applications of an entity model in a simulated system are discussed. A detailed description of the general simulation program is given together with a manual for use of the program in the Appendix to the report.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
*SIMPO						
*Simulation models						
Modeling techniques						
*Computerized model--application						
Personnel subsystem						
*Entity simulation model						
Optimal allocation						
Optimized performance						
Computer programs						
*Optimization techniques						
*Statistical design						
Parameter subroutines						
Personnel policies--evaluation						

SUPPLEMENTARY

INFORMATION

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